nuclear war means in the real world. They see a nuclear exchange as a game of chess where the "winner" is the one who has lost the fewest pieces. The player who retains his king, two rooks and a knight is in a better postion than the player with just his king and a bishop. However, in a nuclear war, the pawns that are knocked off the board are real people, my friends, your neighbors, perhaps my girlfriend or perhaps people close to Locker. The pieces cannot be set up again later to start a new game. In the face of such losses it is possible that we and our military and political leaders might lose our emotional detachment and be tempted to make irrational decisions.

It has been estimated that even in the type of surgical first strike described by Locker, 10 to 20 million Americans would be killed by blast, by fallout and perhaps, here and there, by an errant missile that was aimed at a silo in Nevada, but landed on Toledo, Ohio, instead. It goes without saying that Locker is much less concerned with this than the fact that we might subsequently be tempted to "surrender." He dismisses too quickly the possibility that we might also be tempted to use some of our remaining warheads on soft civilian targets. The fact is that even after a first strike we will still have more than enough warheads left to completely destroy the Soviet Union as a viable society. The mere *possibility* that we might do so (even though it would seem an irrational choice to Locker) should be enough to deter the Soviet Union from launching a first strike in the first place.

Our only experience with nuclear war comes from a situation where one side had a handful of small nuclear devices (of which it used two) and the other side had none at all. The destruction, nevertheless, was considerable. At present the US and the USSR each have in excess of 10 000 warheads. We probably have enough warheads to destroy the USSR 50 times over. After a first strike we may be left with merely enough warheads to destroy the USSR only 5 times over.

Anyone who considers an all-out nuclear confrontation between the US and the USSR as a "game" that can be "won" rather than an exercise in mutual mass suicide, and feels that the safeguard ABM system or the MX missile system (whether deployed on racetracks in Utah, submarines off the coast of California, or railroad cars on the BMT subway) would make a difference, is just plain crazy.

Finally let me add parenthetically that military analysts always ignore the "Murphy Factor." Murphy's sixth law, which applies particularly to high technology systems, states that the more complicated a contraption is, the less likely it is to work or, in other words, "The reliability of any device is inversely proportional to the number of its working parts." In high technology military procurement, delay, cost overruns and equipment that *never* lives up to design specifications are the rule rather than the exception. Playing three-card monte with twenty-ton ballistic missiles can be a very complicated business. If, in a situation critical to the foreign policy of the United States, the US military was unable to master a fleet of eight helicopters in good working order for the attack on the US embassy to free the hostages in Iran, do we really think that they will be able to make the MX missile system work as planned under combat conditions? More than likely we will find many of our missiles neither hidden in the launch sites nor protected by silos, but sitting ducks in the middle of the racetracks because the transporters have developed overheated engines, broken axles or flat tires.

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Effects of undulators

Ednor Rowe's article in May (page 28), which summarizes the synchrotron radiation facilities now available in the US, provides valuable information to those planning experiments utilizing synchrotron radiation. On one point, however, his statements do not conform to our experience at Stanford, and we feel that this point should be discussed further to avoid errors in the planning for experiments and facilities.

Undulators, which emit synchrotron radiation that is sharply peaked at certain wavelengths, have been installed at several machines. In discussing their use, Rowe states: ". . . the effects of the undulator on the beam dynamics of the storage ring are such as to seriously degrade the brightness of the radiation from the normal bending-magnet points." As mentioned in our article in the same issue, an undulator has been installed in the SPEAR storage ring at the Stanford Linear Accelerator Center. The storage ring operates for synchrotron radiation work in the energy range 3 to 3.5 GeV. The undulator is a 30 period, permanent magnet device with a field variable (by varying the gap) from 500 gauss to 2.3 kG.

The effects of this device on the stored beam have been studied. As expected there is a negligibly small increase in the vertical focusing in the lattice, caused by the edge focusing in the undulator. The fields of the undulator do also stimulate a sum resonance where the horizontal and vertical beta-

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tron frequencies are related by the expression: $3\nu_x + \nu_y = 21$.

This latter effect is unexpected and the causes are not yet understood, but the resonance is extremely narrow and can easily be avoided by choice of operating parameters.

We find no other effects on the stored beam. The emittance of the electron beam, and hence the brightness of the synchrotron radiation beams derived from other source points (both bending magnet and wiggler), is not changed by a measurable amount. We expect to use the undulator in the future as a routine part of the experimental facilities without any negative impact on the operation of the ring and other beam lines.

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Optical phase conjugation

The review of optical phase conjugation by Concetto Giuliano (April, page 27) should perhaps be amended on two points. First, Giuliano says that phase conjugate resonators "will not possess longitudinal modes that depend on the cavity length." I assume he refers here to the actively pumped or four-wave-mixing type of phase conjugator, since this is the only type that has no constant frequency offset incorporated in its reflection. (Although I am not aware of any rigorous proof, most physicists seem to believe that only an actively pumped device can produce true spatial phase conjugation without an inherent frequency offset.)

It is then correct that the central resonance of a phase conjugator resonator will be located exactly at the pumping frequency ω_0, independent of cavity length L. One can also show, however, that such a resonator with an ideal phase conjugator will have a complete family of matched pairs of "half-axial" modes which are spaced about the center frequency ω_0 by $\Delta f = c/4L$ rather than the usual $c/2L$. An extensive review of all the spatial and temporal mode properties of such a phase conjugate resonator will appear in a forthcoming volume.[1]

Second, I believe reviews of phase conjugation should mention and perhaps even emphasize that all conventional four-wave phase-conjugate reflectors inherently produce not only a reflected and phase conjugated wave in the backward direction, but also an *amplified* and *non*-phase-conjugated wave in the forward direction. Indeed the forward gain is fundamentally larger than the reverse reflection, so that the generally unwanted and unconjugated forward wave carries away more power than the wanted reflection. Until this defect in real phase conjugators is overcome, it is difficult to see how some of the predicted applications of phase conjugation can use useful.

References

1. A. E. Siegman, P. A. Belanger, A. Hardy, "Optical Resonators Using Phase Conjugate Mirrors," in *Optical Phase Conjugation*, ed, R. A. Fisher, Academic Press, to be published.

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THE AUTHOR COMMENTS: My brief discussion of a phase conjugate resonator was intended to apply to a hypothetical "black box" conjugator which is equivalent to an actively pumped or four-wave mixing type of conjugator whose spectral response is narrow compared with $c/4L$. Siegman is quite correct with regard to the existence of half-axial mode pairs; in fact workers at our laboratory have recently observed for the first time[1] the existence of these modes in a continuously running phase conjugate resonator.

References

1. R. C. Lind and D. G. Steel, "Continuous-wave Dye Laser with a Phase-Conjugate Mirror," presented at CLEO, the Conference on Lasers and Electro-Optics, Washington, D. C. 10–12 June 1981.

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More on synchrotron radiation

At one point in his informative article on facilities in the US for synchrotron radiation research in May (page 28), Ednor Rowe conveys an impression which needs correction. In discussing the early Cornell work on the 230-MeV synchrotron, he indicates that Tomboulian (Diran H.) and Hartman were denied further access to the synchrotron following the promise shown in their first soft x-ray results. As one of the participants in that work, I had not heard of this denial. From the very first when I went to Director Bob Wilson and proposed that we be allowed to investigate the radiation, he and others were enthusiastic. We would use a vacuum grazing incidence spectrograph which Tomboulian had available and which could be moved over to the machine. In planning, setting up and the actual running, the machine operators and high-energy physicists were all cooperative; we would have been helpless without their aid. If there was any denial to us of further work, it came in the crowded conditions, the need for its being a pirating operation and the general inconvenience.

So Tomboulian went back to his spark sources for his soft x-ray work and I went back to my hydrogen lamp for light in the Lyman alpha region of the spectrum. At the time of his untimely death, not having lost interest in the synchrotron possibilities, Tommy was actively involved with the Cambridge group in designing a facility there to exploit the radiation.

Rowe does not cite the work of Peter Joss on the next Cornell machine, in which he investigated the polarization of the radiation, first demonstrating the ellipticity found out of the plane of the orbit. I believe the high-energy people at Cornell have been very supportive of work with their radiation, and any denial really came in our own reluctance to pursue it.

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Microfiche journals

I read with interest your editorial on the electronic library in May (page 152). It also brought to mind an option which could be implemented with relative ease and rapidity, namely the promotion of the microfiche edition of scientific journals as a same-cost alternative to the paperback edition now received by individual members of Member Societies of AIP. For example, the Institute of Physics (UK) offers microfiche editions of its scientific journals to individual members at the same member cost as for paper editions, whereas AIP offers miniature editions mainly in archive-oriented entire-volume microfilm at non-member prices.

For individual members, microfiche editions would save precious office space and thus be an incentive for subscribing to more than one journal. For publishers, they are less expensive to produce and distribute than paper editions—if the non-member prices of the Institute of Physics (UK) are any indication—and they may even increase circulation.

Expected durability is no obstacle: one to four centuries for microfiche versus fifty years for paper binding. A portable or lap-held fiche reader can be purchased for $100 to $200.

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Nuclear hostages?

I greatly appreciate Wolfgang Panofsky's article "Science, Technology and the Arms Race" (June, page 32). I